7B)

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(71) Applicant: Hewlett-Packard Company
3000 Hanover Street
Palo Alto, California 94304 (US)

(72) Inventor: Black, Chuck A.
3415 Cook Street
Rocklin, California 95677 (US)

(74) Representative: Powell, Stephen David et al
WILLIAMS, POWELL & ASSOCIATES 34
Tavistock Street
London WC2E 7PB (GB)

(54) **Determining physical topology across repeaters and bridges in a computer network.**

(57) Localized port arrival information is processed for individual hubs and bridges in an extended computer network. A particular device is chosen as a starting reference. Device connections on each port of the particular device are then recursively determined. Afterwards, device connections for apparent tree nodes attached to said starting reference are determined.

EP 0 511 851 A2

Jouve, 18, rue Saint-Denis, 75001 PARIS

This invention relates generally to computer networks, and more particularly to different stations in a network interconnected through bridges and hubs.

For simple computer networks such as a LAN (local area network) located on a small office suite on a single floor of a building, it has been relatively simple to determine the actual network layout by inspection. However, networks now include many stations through the use of 12-port and 48-port repeaters called hubs, and different networks are often joined together by bridges so that data packets are sent across different networks to computer devices located in many different buildings and locations. It is not unusual to remove stations from a network and add other stations without telling the network administrator. Accordingly, a need has arisen for automatically collecting detailed accurate information about the layout and topology of computer networks.

It is an object of the invention to provide a method for determining the arrival port of message packets received by an interconnect device such as a hub, obtaining from the message packet an identification of the sender, and then storing for easy accesibility a list of each port on the hub and its associated computer device. A related object is to obtain this arrival port information accurately, without acquiring false information based on spurious pulses and without interfering with any management functions which occur at the hub.

Another object of the invention is to provide a method for selectively listening at many different hubs for the arrival of message packets from a particular sender, and for periodically initiating a change to allow selective listening for the arrival of message packets from another particular sender.

Another object of the invention is to provide a method for instigating a particular station to send out an announcement packet to all multiple port repeaters such as hubs, and to bridges, with only minimal processing and distribution, and to enable individual hubs and/or bridges to identify which one of their ports is connected to that particular station.

Another object of the invention is to provide a method of processing the localized port arrival information for individual hubs and bridges in an extended network so as to determine and display the physical topology of the various network segments.

These and other objects will become apparent to those skilled in the art in view of the drawings and related written description of a presently preferred embodiment of the invention as set forth below. In the drawings:

Fig. 1A shows a typical computer network layout having multiport repeaters (hubs) connected directly together as well as interconnected through a bridge;

Fig. 1B shows a typical LAN hub of Fig. 1A having individual devices connected through twisted wire pairs to specific ports on the hub;

Fig. 2A is a schematic representation of the interconnect panel for a 48-port managed hub which incorporates the present invention;

Fig. 2B shows a preferred wiring pattern for interconnecting 8-wire twisted pair cabling with the 48-port managed hub of Fig. 2A;

Fig. 3 shows a LAN layout having 12-port and 48-port managed hubs which incorporates the present invention;

Fig. 4 shows a schematic diagram for the managed hubs of Fig. 3;

Fig. 5 is a timing diagram for a managed hub showing the difficulty of matching the correct port identification with its corresponding packet;

Fig. 6 is a block diagram for a 48-port managed hub featuring a preferred embodiment of the invention;

Figs. 7A-7C are flow charts for the managed hub of Fig. 6 showing how port arrival identification is achieved for computer network packets received by the managed hub of Fig. 6;

Fig. 8 is an exemplary port arrival matrix for a 12-port managed hub;

Fig. 9 is an exemplary port arrival matrix for a 48-port managed hub;

Fig. 10 is a mapping address search flow chart for multiport repeaters such as the 12-port and 48-port hubs of Fig. 3;

Fig. 11 shows the mapping address objects for the hubs of Fig. 3 which are programmed to listen for packets originating from a network device identified by its address X;

Fig. 12A shows a computer network layout having at least one differently designed hub, with a managed hub and a managed bridge both incorporating the present invention;

Fig. 12B shows how the network topology of Fig. 12A appears to the mapping application;

Fig. 13 shows a typical packet format for extended network mapping announcements sent to devices in an Ethernet-type of computer network;

Fig. 14 is a flow chart for determining the physical topology across repeaters and bridges in an extended computer network;

Fig. 15A is a schematic diagram of an extended network having two LANs;

Figs. 15B and 15C are exemplary tree diagrams used to implement the flow chart of Fig. 14 with respect to the extended network of Fig. 15A; and

Fig. 16 is a network topology map display that is produced by the flow chart of Fig. 14.

Generally speaking, the invention can be implemented in computer networks of various types and configurations, and the particular layouts shown are for purposes of illustration only. In that regard, the network layout of Fig. 1A shows how certain ports 20, 22 of their respective hubs 24, 26 receive packets from multiple senders. In contrast, other ports such as 28, 30 receive packets from one and only one sender (unless there is a configuration change made replacing one device with another or replacing one device with a multiport device such as a hub or bridge). Figure 1B shows a hub with a 12-port modular adapter 32 for connecting individual ports to network devices through twisted-pair cable also known as the IEEE 802.3 10 BaseT standard.

Fig. 2A shows the back interconnect panel for a 48-port hub having in addition an AUI port 34 and a BNC (coax) port 36. The manner of hooking up the four pair twisted wire cable to each port such as 38 is shown in Fig. 2B.

In a hub such as shown in Fig. 2A, it is useful to monitor the traffic on each port and keep track of the station address of the node connected to each port, as well as keep track of other detailed information about the traffic on that port. In some implementations of a hub, an off-the-shelf network interface controller (NIC) chip 40 is used for network management functionality and this controller chip is not integrated with the rest of the repeater hardware of the hub. The repeater 42 may tell the firmware 44 the port number of each packet repeated using a special circuit. Essentially such a hub may be structured as shown in the schematic diagram of Fig. 4.

If the NIC chip 40 is run in promiscuous mode (a mode in which it listens to all packets, instead of only those addressed to it), it is possible to correlate the packets received by the NIC with the port numbers for the repeater to obtain detailed per-port network statistics. This correlation can be accomplished by the routine set forth in the following table:

TABLE I

```
<NIC Interrupt Service Routine>
While the NIC has a new packet {
     Note the number of activity indications sent by the repeater
     Increment count of consecutive packets
     If there have been n consecutive packets without getting to the "idle" loop
         Exit promiscuous mode and only listen for network management packets
     If the NIC heard a packet, but the repeater did not, do not identify the port
     If the NIC heard a packet, but the repeater heard >1 packet, do not id port
     If the NIC heard a packet and the repeater heard exactly one packet then
         If the repeater heard exactly one packet for each of the previous packets
         serviced by this interrupt
             Identify the packet as coming from this port
         else
    (*)      Do not identify the port of this packet
  }
```

If the network monitoring is overloading the hub and starts to degrade the response time to requests from a network management application, the hub will temporarily exit promiscuous mode and listen only to the network management packets addressed to it.

The method for correlating the port number with packets received by the NIC is complicated by several factors. For example, it is necessary for the firmware to respond to packet interrupts quickly -- otherwise it will be overrun with packets and/or port numbers. Interrupts can be disabled at different times while the firmware is performing other network management related tasks. Further impairing interrupt response time is the relatively low-performance microcontroller which is used to reduce costs.

As an additional example, sometimes the repeater will hear small runt packets which are not heard by the NIC. In other words, there is not always a one-to-one correspondence between packets heard by the NIC and port numbers from the repeater.

Another situation arises with small back-to-back packets and is most common when these packet bursts arrive when interrupts happen to be temporarily disabled. The NIC interrupt occurs slightly after the port number is indicated by the repeater. In the diagram of Fig. 5, the network activity line is high when there is network activity. The NIC Interrupt Service Routine (ISR) line is high when executing the MIC Interrupt Service Routine. In the diagram of Fig. 5, the portion 44 indicates port activity for packet Rx1 and the corresponding portion 46 indicates the dma of the same packet RX1 by the NIC.

At point A in Fig. 5, the port for packet Rx1 is not known since the ISR observed two port numbers from the repeater (i.e., the ISR does not know if the extra port number is for a packet or if it is from a tiny runt heard by the repeater but not by the NIC). At point B, the ISR sees exactly one port number and would normally misidentify the port of packet Rx2 as the port of packet Rx3. The routine of Table I solves this problem.

Fig. 6 shows a presently preferred embodiment for the invention in a managed hub implementation. A bus is used to interconnect the network management microprocessor, an EEPROM for code storage, a RAM, a network interface controller, and port number registers. The RAM includes space for normal data and packet storage, as well as space for implementing various features of the invention. The port arrival matrix of Fig. 9 is stored at one portion, the mapping address search objects of Table II are stored in another portion, and a third portion is used for the NIC packet receive buffers.

LAN traffic comes into a 50 port repeater causing an entry into a port number register having sufficient bits to identify all the input ports, and also causing an activity indication to the network management microprocessor. If in promiscuous mode (see the flow chart of Figs. 7A, 7B and 7C), then the NIC receives and monitors all incoming packets. Otherwise only the packets addressed to the hub are processed and the other packets are merely resent. The mapping address search objects are used in both hub and bridge implementations (see the flow charts of Figs. 10A and 10B which depict the map address procedure purely from the device's point of view. Note the differences between the hub (Fig. 10A) and the bridge (Fig. 10B) implementations. The Map Address Objects themselves are shown in the following table:

TABLE II

MAPPING ADDRESS SEARCH OBJECTS

```
mapAddress OBJECT-TYPE
   SYNTAX  OCTET STRING
   ACCESS  read-write

   DESCRIPTION
      "When object is set a map address search begins.  If the address
      is detected on only one port, then the mapPort object is set to
      the port number on which the address was detected.  Bridge:  the search
      completes immediatly.    Hub:  the search will continue until a
      new address is placed into mapAddress."
mapState OBJECT-TYPE
   SYNTAX  INTEGER {
         PS_NONE(0),
         PS_SINGLE(1),
         PS_MANY(2)
      }
   ACCESS  read-only

   DESCRIPTION

      "It will be set to PS_SINGLE if the map address is detected on one
      and only one port.  If the map address is detected on more than
      one port, map state is set to PS_MANY."


mapPort OBJECT-TYPE
   SYNTAX  INTEGER (0..65535)
   ACCESS  read-only

   DESCRIPTION
      "The port number on which the map address was detected.  If map
      state is PS_NONE or PS_MANY then this object is not valid."
```

The various mapping address objects are shown in Fig.11 wherein each of the devices Q,T and X are programmed to listen for packets coming from the device having an S address.

To map a network of hubs, a mapping application needs to know which devices are connected to each of

the hubs ports. The mapping application is able to poll the network and find out the addresses of each hub, but to make a complete map, it must know the ports on which each hub is connected. Some ports may be connected to hundreds of nodes and it is not feasible for each hub to keep a list of node addresses for each port.

To solve this problem, the Map Addresses object has been created. The mapping application simply sets the Map Address on a hub and the hub will listen for packets transmitted by the device specified by Map Address. When the Map Address is heard, the hub will record the port number on which the Map Address is heard and the mapping application will use this information to lay out the network map.

In the network specified in Figure 17, Hub 2 does not know which LAN segment Hub 1 is attached to, since many nodes are probably on each LAN segment. The mapping application can set the Map Address object on Hub 2 to the address of Hub 1. Later, when Hub 1 transmits a packet, Hub 2 will hear it and identify the port on which Hub 1 is connected.

TABLE III

MAPPING ANNOUNCEMENT

```
announceAddress OBJECT-TYPE
        SYNTAX    OCTET   STRING
        ACCESS    write-only
```

DESCRIPTION

"When set to any MAC multi-cast address, the device will transmit three identical packets, each with the MAC source set to the device's MAC address, the MAC destination to the multi-cast address, the DSAP is F8.

These packets will traverse bridges, allowing them and devices connected to them to learn the port connectivity of the multi-casting device".

To map a network of hubs, a mapping application needs to know which devices are connected to each of the hubs ports. The mapping application is able to poll the network and find out the addresses of each hub, but to make a complete map, it must know the ports on which each hub is connected. Some ports may be connected to hundreds of nodes and it is not feasible for each hub to keep a list of node addresses for each port. The Map address object previously discussed solves much of this problem, but in figure 18, there is a problem with basic use of the Map address object in that Hub 1 will never hear packets from Hub 2, since all communication between Hub 2 and the mapping application is filtered by the bridge.

The mapping application could look in the address table maintained by the bridge to find out how the hubs are connected, but this does not always work, since not all bridges have an address table which is readable by the mapping application. Also, using information gathered from the hubs is much simpler than incorporating the address table information gathered from bridges. To enable Hub 1 to hear packets from Hub 2 and identify the port on which it is connected the mapping application must make Hub 2 transmit some sort of announcement packet which can be heard by Hub 1. To do this, there are several alternatives:

A) Have Hub 2 broadcast a packet which goes across the entire network. This alternative will accomplish the mapping objective, but almost every single node on the entire network will need to process the packet and this will cause a significant amount of useless broadcast traffic which does not need to be heard by all nodes.

B) Have Hub 2 transmit a packet addressed directly to Hub 1. This alternative will also accomplish the mapping objective, but on a large network, the mapping application would need to tell the hub to transmit a packet to every other hub on the network, adding a significant amount of overhead to the mapping process.

C) Have Hub 2 transmit a multicase packet heard only by hubs. This is the ideal alternative, because the packet will go through the bridge and it will only be heard by other hubs which listen for the multicast address. This is the method by which hub network mapping is done.

This invention solves the problem of determining the physical topology (that is, the interconnection of lan serpents and interconnecting network devices) of a network. This is done automatically and produces a representation of the network which can be used for fault detection and diagnosis, performance characterization, and security.

Without the automatic determination of the physical topology of the network, the onus of mapping out the

topology is on the human manager of the network, and is thus highly prone to error.

This invention uses mapping information available from repeaters and bridges to build a representation of the network. These repeaters and bridges are hereafter referred to as "networking devices". A networking device connects two or more physical networking serpents (coax, broadband, twisted-pair, fiber, etc) through its ports.

A networking device will have two or more ports. Through these ports, the device "hears" other devices and end stations (e.g personal computers) which are part of the network. A networking device hears other devices and end stations out of one and only one port.

For the following description, assume the following network shown in Fig.19.

The algorithm first discovers the existence of bridges and repeaters in the network, resulting in a list of these networking devices:

-->d1-->d2-->d3-->d4-->d5-->d6-->

The algorithm then selects a device arbitrarily from the list (although a simple heuristic could easily be applied to choose a device which would enhance the performance of the algorithm). From that device, the process of determining network topology begins. This is accomplished by determining where all of the other devices in the network are with respect to that device, by hearing out of which port that device is located.

For example, if device d2 is connected to a lan cable which is connected to d1's port 1, then d1 hears d2 on port 1.

The resulting network after this first step (from the point of view of arbitrarily chosen device d1) may look as follows.

```
      d1
    / | \
  d2 d3  d4 d5 d6
```

After this step is accomplished, it is possible to recursively visit each of the resulting "nodes" of this tree, and to eliminate those devices which are not actually directly connected to the calling device. In the above example, we would descend from d1 down to the node which contains d4,d5,d6. The goal here would be to eliminate those devices which are not directly connected to d1.

Looking at the original diagram, one can see that only d4 is directly connected to d1; d5 and d6 are connected to d1 through device d4. Algorithmically, the procedure for eliminating d5 and d6 is as follows:

First, select a device (for this example, we choose d4) and determine the port on which the calling device (d1) is heard. Then, try to eliminate the other nodes by showing that they are heard on a different port than the port on which the calling device is heard

In the example, and choosing d4 as the "eliminator", if d4 hears d1 in port 1, and then hears d5 on port 2, then d5 is eliminated, because we have proven that d4 stands between d1 and d5 in the topology.

Applying this process recursively, the resulting hierarchy is a representation of the physical topology of the network. In the example, the resulting hierarchy would look as follows:

```
      d1
    / | \
  d2 d3  d4
           \
            d5,d6
```

This representation of the network can then be used to draw a map of the network which looks like the original picture.

The value of automatically deriving the topology versus manual attempts, can be easily seen.

Figure 13 shows a typical frame format which has the source address and destination address which are used in practicing this invention. Most packets are about 64 bytes long. Figure 12 makes it clear that a non-managed hub or a managed hub that is of a different design will not be recognized as a true hub (see Fig. 12B).

Figure 16 shows a network layout different from the other layouts in the drawings, and indicates the ability to draw a topology based on the information automatically acquired by practicing the unique procedures of the invention. The numbers indicate the Internet Protocol addresses, and H12 is a 12 port hub, H48 is a 48 port

hub, HF is a fiber hub and BRM is a remote bridge which B10 is a local 10 MB bridge.

Of course, the invention is not limited to the examples shown, but can be modified and varied, all within the scope of the following claim.

Claims

1. A method for processing localized port arrival information for individual hubs and bridges in an extended computer network, including choosing a particular device as a starting reference, and then recursively determining device connections on each port of the particular device, followed by determining device connections for apparent tree nodes attached to said starting reference.

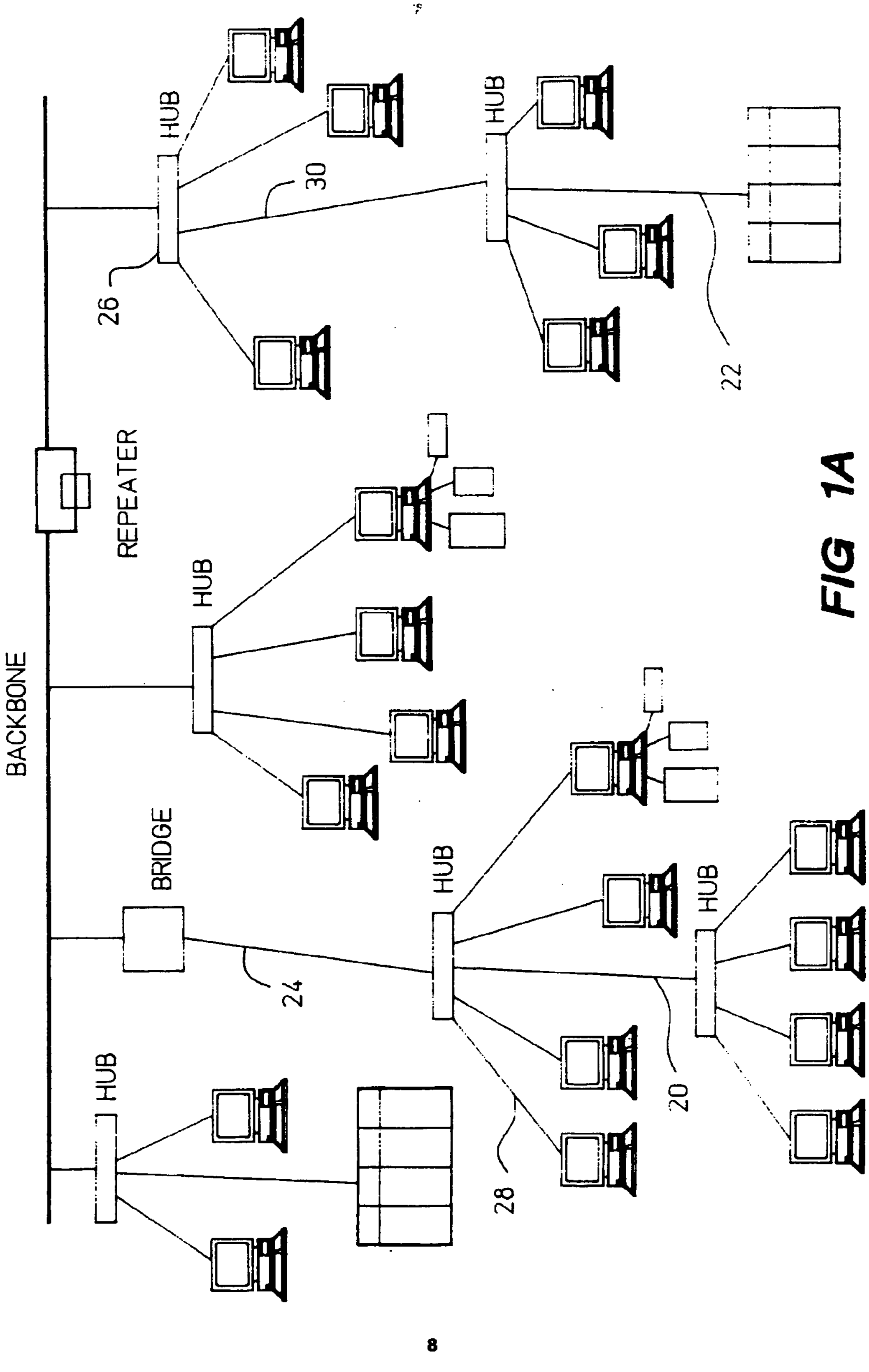

BACKBONE
REPEATER
BRIDGE
HUB
HUB
HUB
HUB
HUB
HUB
20
22
24
26
28
30

FIG 1A

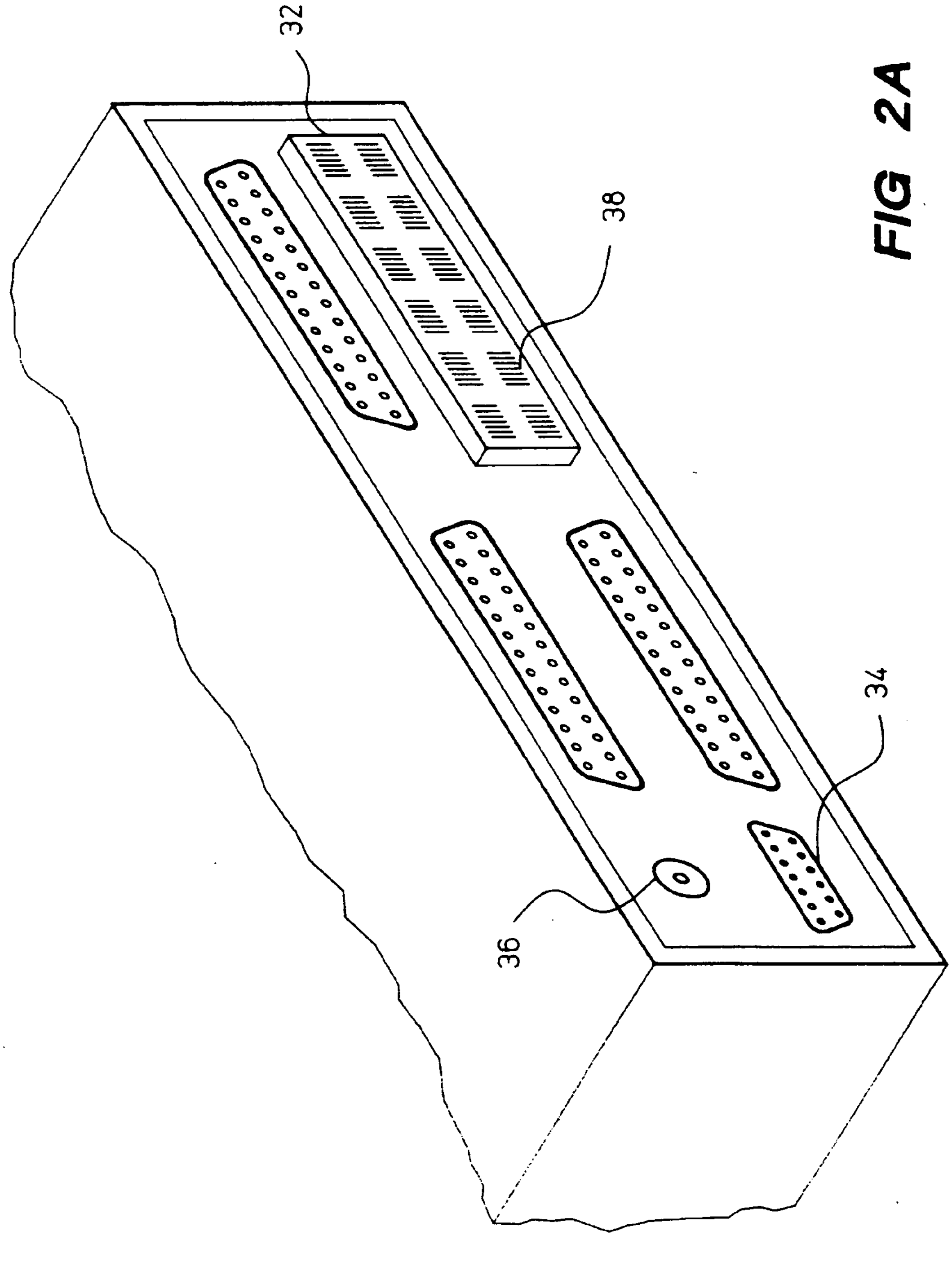
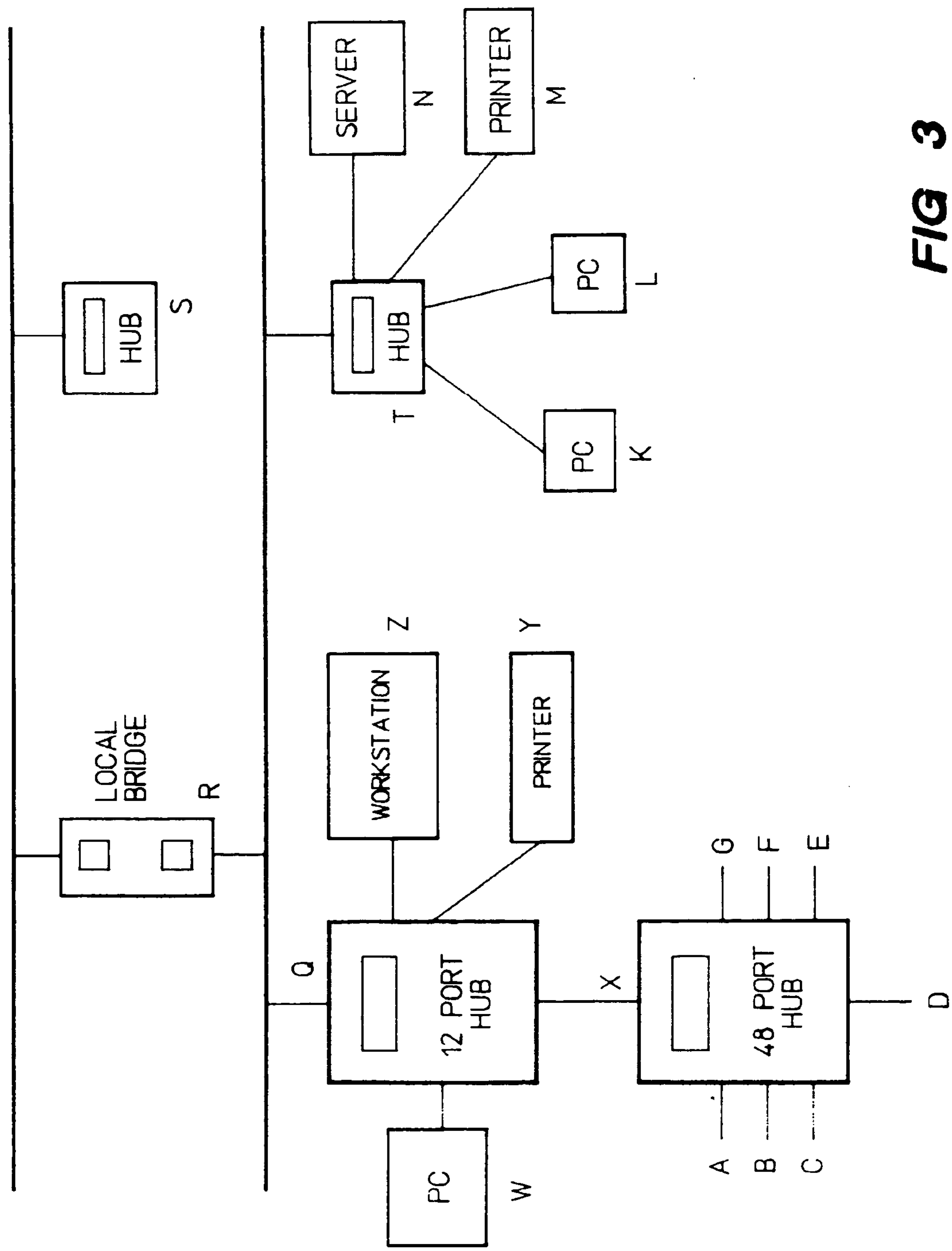


FIG 2A



HUB
S
LOCAL BRIDGE
R
SERVER
N
PRINTER
M
HUB
T
PC
L
PC
K
WORKSTATION
Z
PRINTER
Y
Q
12 PORT HUB
PC
W
X
48 PORT HUB
G
F
E
D
A
B
C

FIG 3

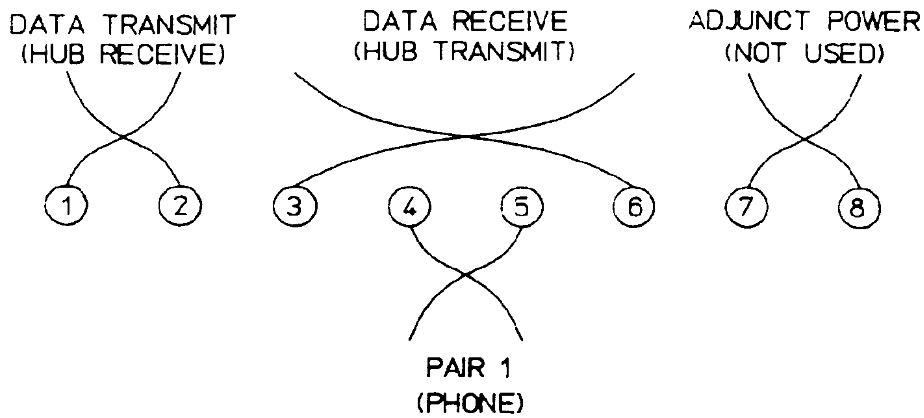


FIG 2B

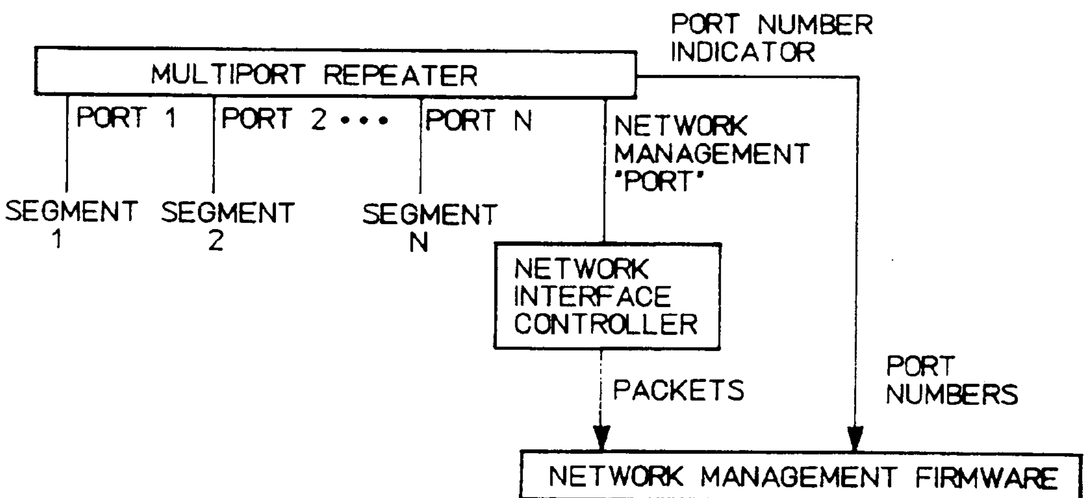


FIG 4

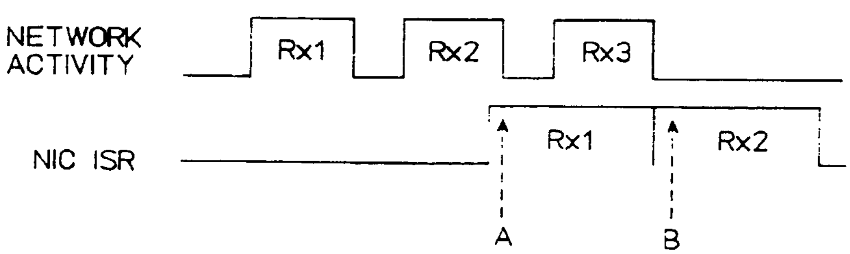


FIG 5

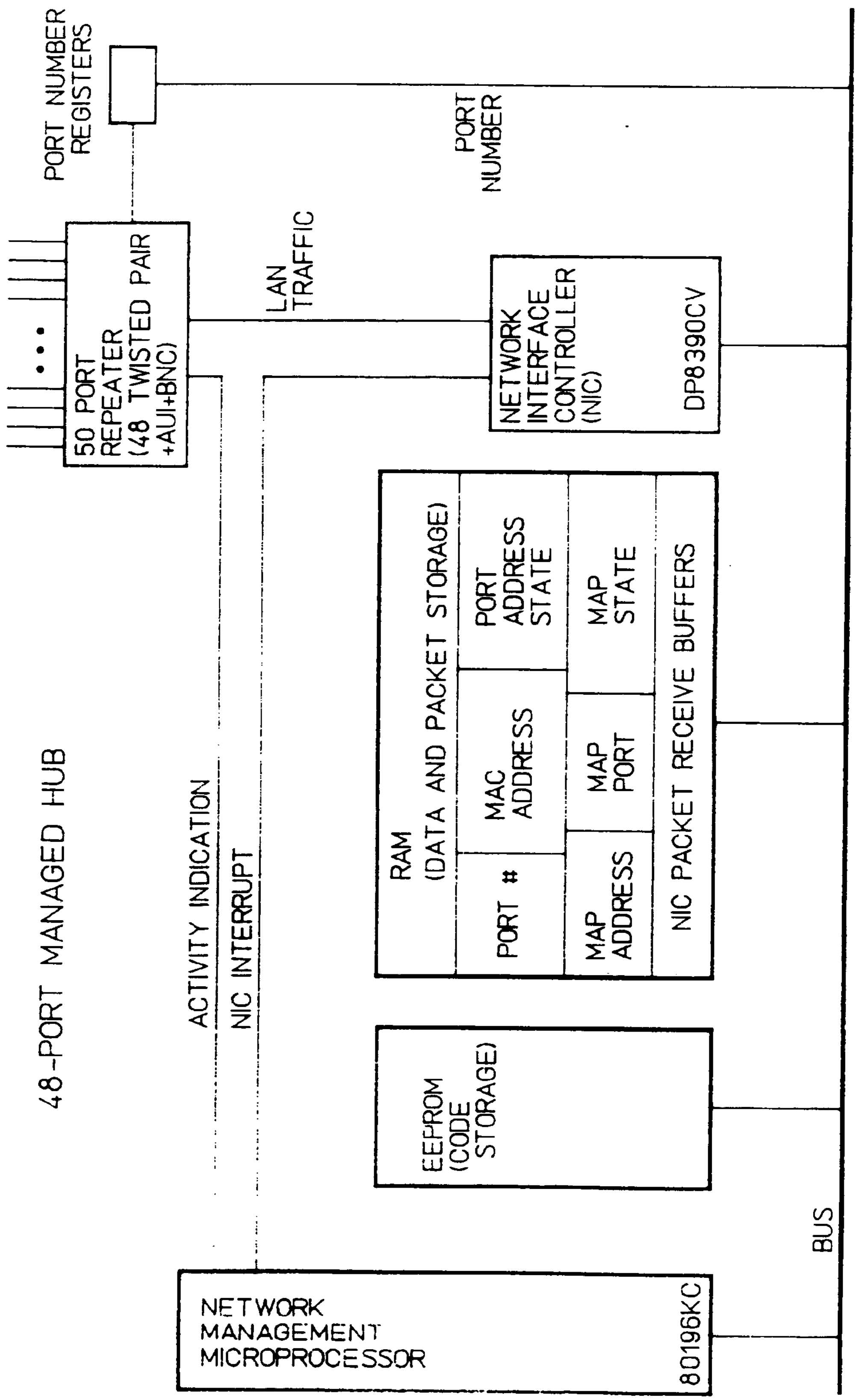

48-PORT MANAGED HUB
PORT NUMBER REGISTERS
50 PORT REPEATER (48 TWISTED PAIR +AUI+BNC)
LAN TRAFFIC
PORT NUMBER
NETWORK INTERFACE CONTROLLER (NIC)
DP8390CV
ACTIVITY INDICATION
NIC INTERRUPT
RAM (DATA AND PACKET STORAGE)
PORT #
MAC ADDRESS
PORT ADDRESS STATE
MAP ADDRESS
MAP PORT
MAP STATE
NIC PACKET RECEIVE BUFFERS
EEPROM (CODE STORAGE)
BUS
NETWORK MANAGEMENT MICROPROCESSOR
80196KC

FIG 6

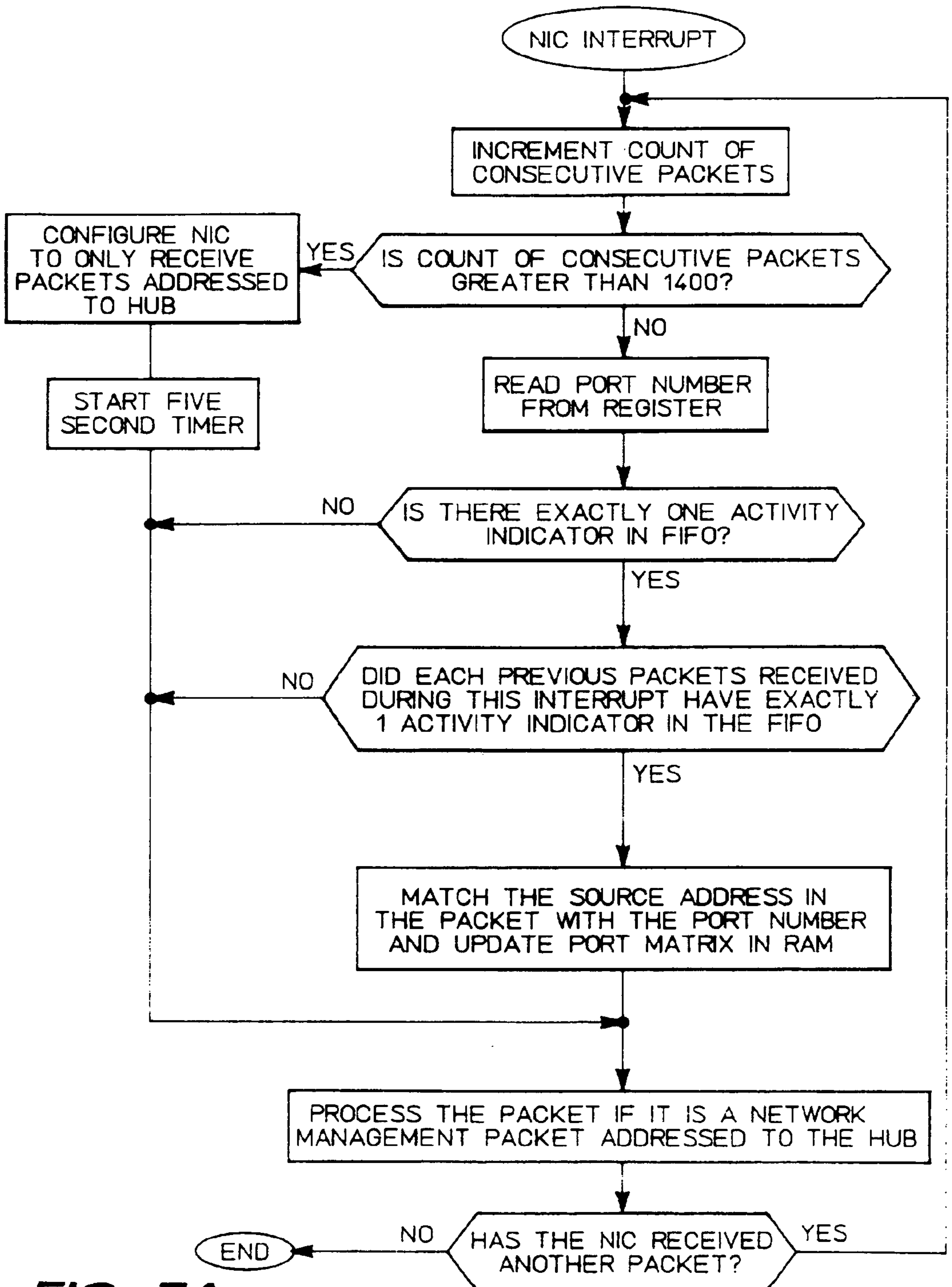
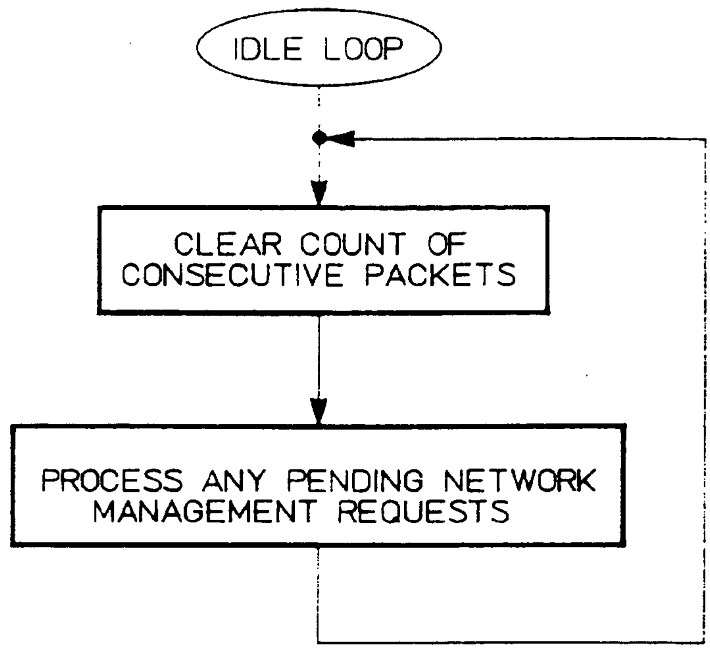
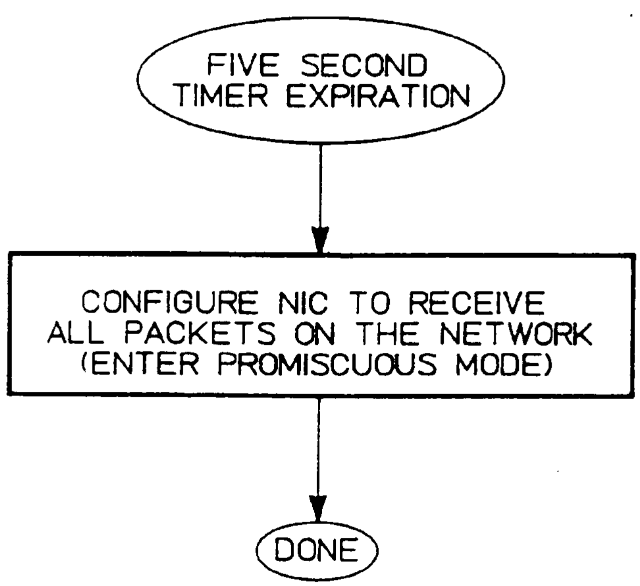

NIC INTERRUPT
INCREMENT COUNT OF CONSECUTIVE PACKETS
IS COUNT OF CONSECUTIVE PACKETS GREATER THAN 1400?
YES
CONFIGURE NIC TO ONLY RECEIVE PACKETS ADDRESSED TO HUB
START FIVE SECOND TIMER
NO
READ PORT NUMBER FROM REGISTER
IS THERE EXACTLY ONE ACTIVITY INDICATOR IN FIFO?
NO
YES
DID EACH PREVIOUS PACKETS RECEIVED DURING THIS INTERRUPT HAVE EXACTLY 1 ACTIVITY INDICATOR IN THE FIFO
NO
YES
MATCH THE SOURCE ADDRESS IN THE PACKET WITH THE PORT NUMBER AND UPDATE PORT MATRIX IN RAM
PROCESS THE PACKET IF IT IS A NETWORK MANAGEMENT PACKET ADDRESSED TO THE HUB
HAS THE NIC RECEIVED ANOTHER PACKET?
NO
YES
END

FIG 7A



IDLE MODE (NOT HAVING PACKETS)

FIG 7B



RE-ENTER PROMISCUOUS MODE

FIG 7C

PORT ARRIVAL MATRIX FOR 14-PORT HUB

PORT #	DEVICE ADDRESS	PORT STATE
1	W	SINGLE
2	X	MULTIPLE
3	Y	SINGLE
4	Z	NONE
⋮	⋮	⋮
14	T	MULTIPLE

FIG 8

PORT ARRIVAL MATRIX FOR 48-PORT HUB

PORT #	DEVICE ADDRESS	PORT STATE
1	A	NONE
2	B	NONE
3	C	SINGLE
4	D	SINGLE
5	E	SINGLE
6	F	NONE
7	G	NONE
⋮	⋮	⋮
47	Q	MULTIPLE
48	•	•

FIG 9

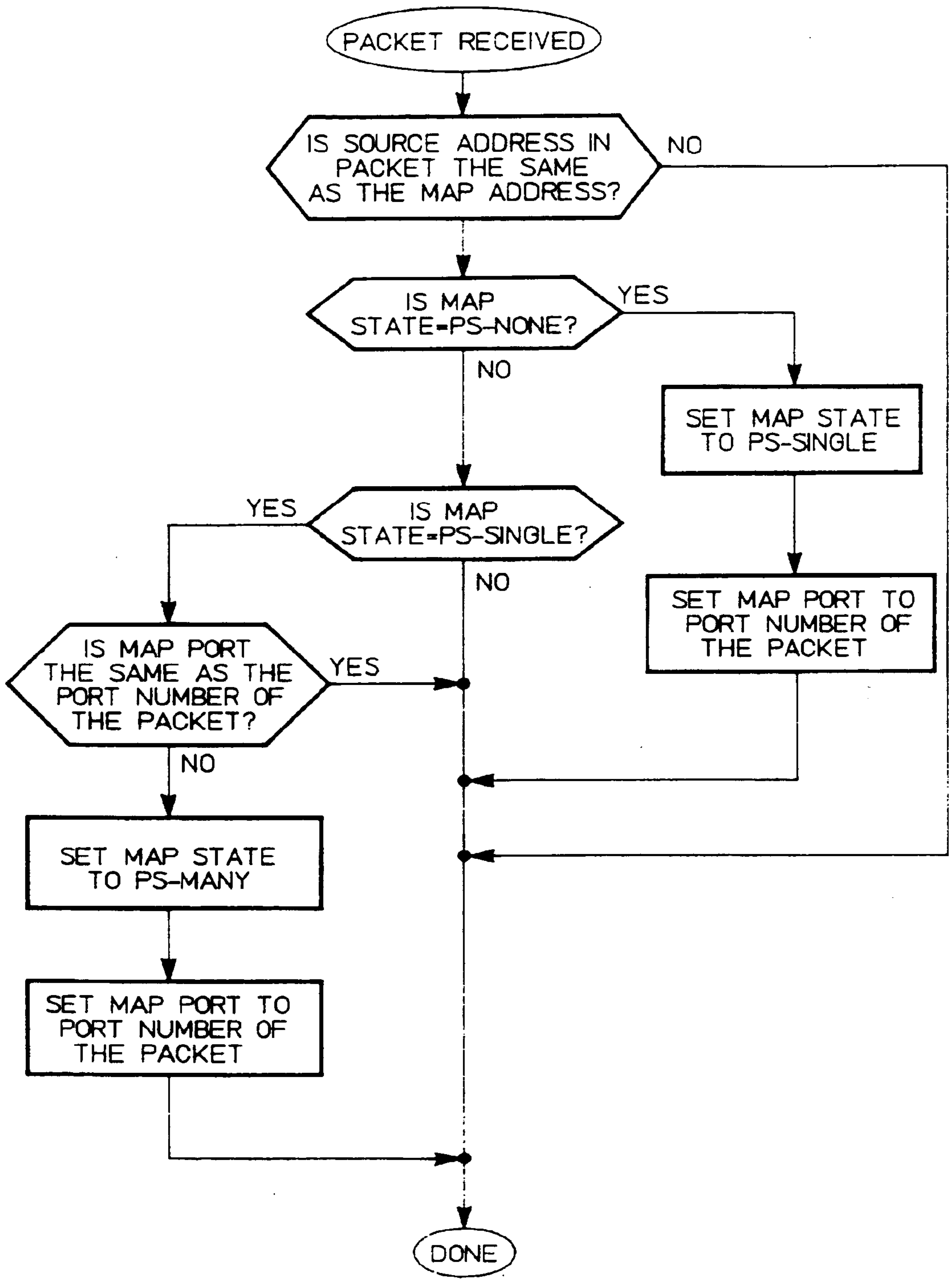
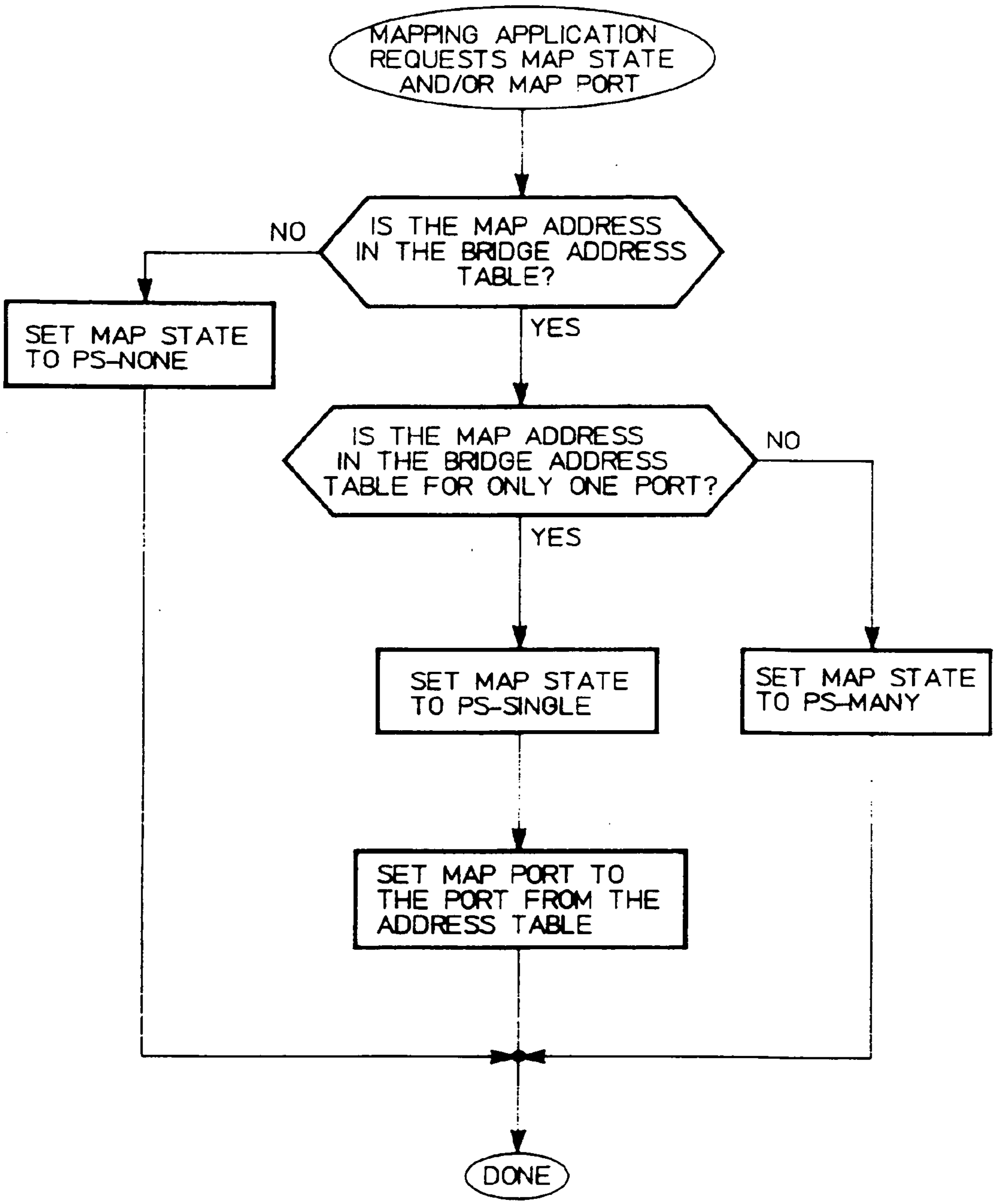


FIG 10A

MAPPING ADDRESS SEARCH-HUB IMPLEMENTATION



MAPPING ADDRESS SEARCH-BRIDGE IMPLEMENTATION

FIG 10B

MAPPING ADDRESS OBJECTS

FIG 11A

MAP ADDRESS	MAP STATE	MAP PORT	THIS DEVICE
S	PS-SINGLE	2	Q

FIG 11B

MAP ADDRESS	MAP STATE	MAP PORT	THIS DEVICE
S	PS-NONE	NOT VALID	T

FIG 11C

MAP ADDRESS	MAP STATE	MAP PORT	THIS DEVICE
S	PS-SINGLE	47	X

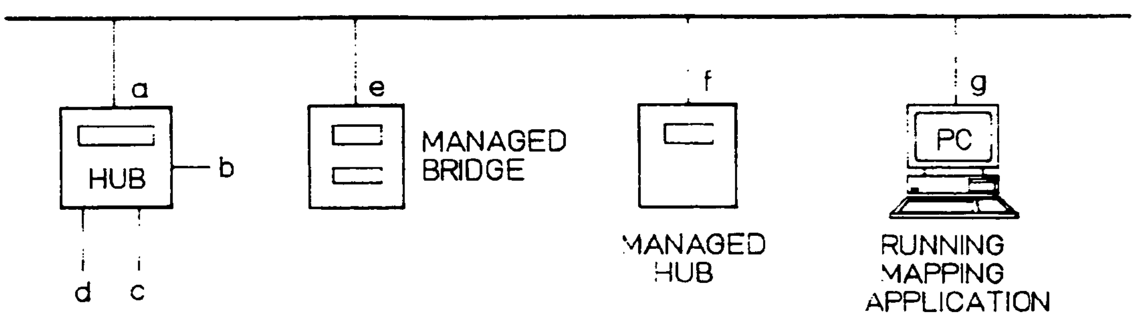


FIG 12A

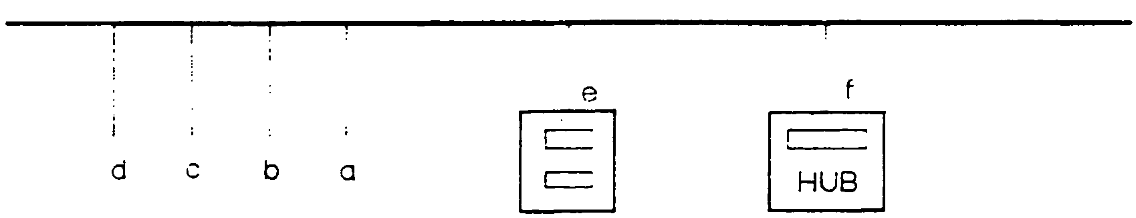


FIG 12B

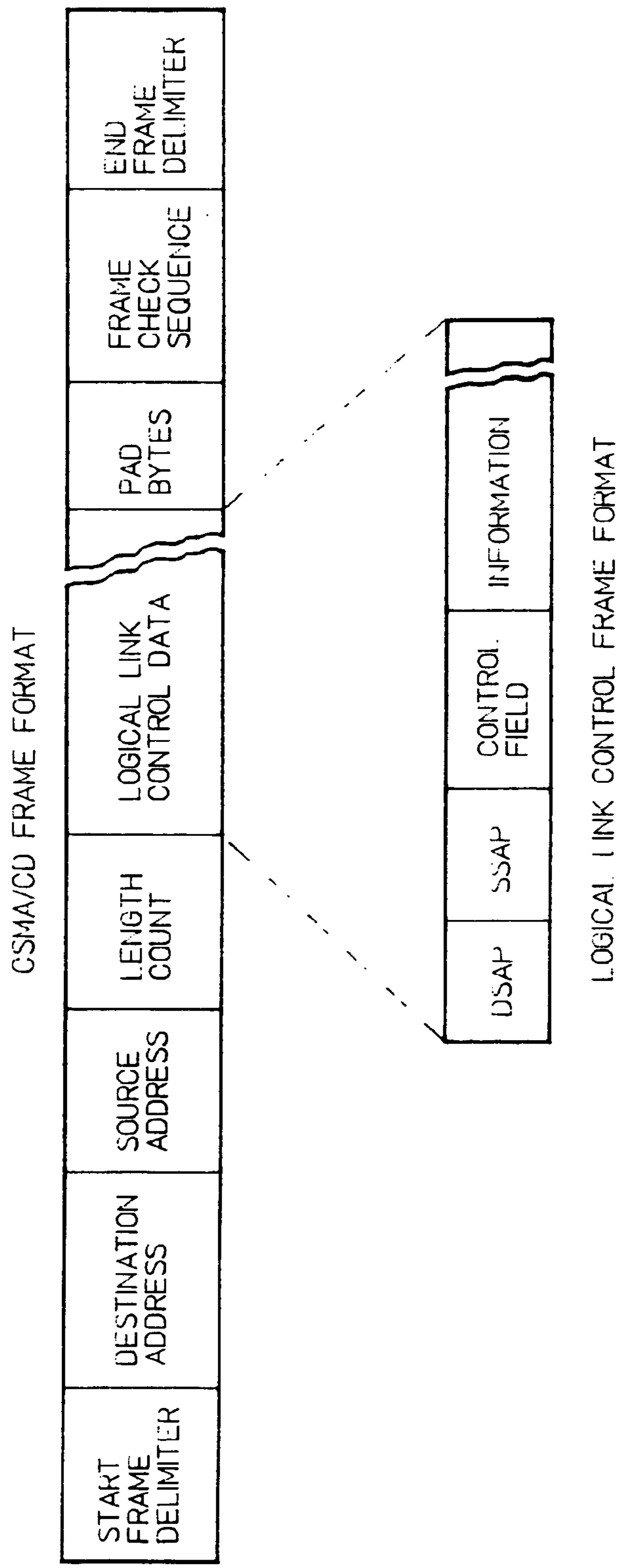
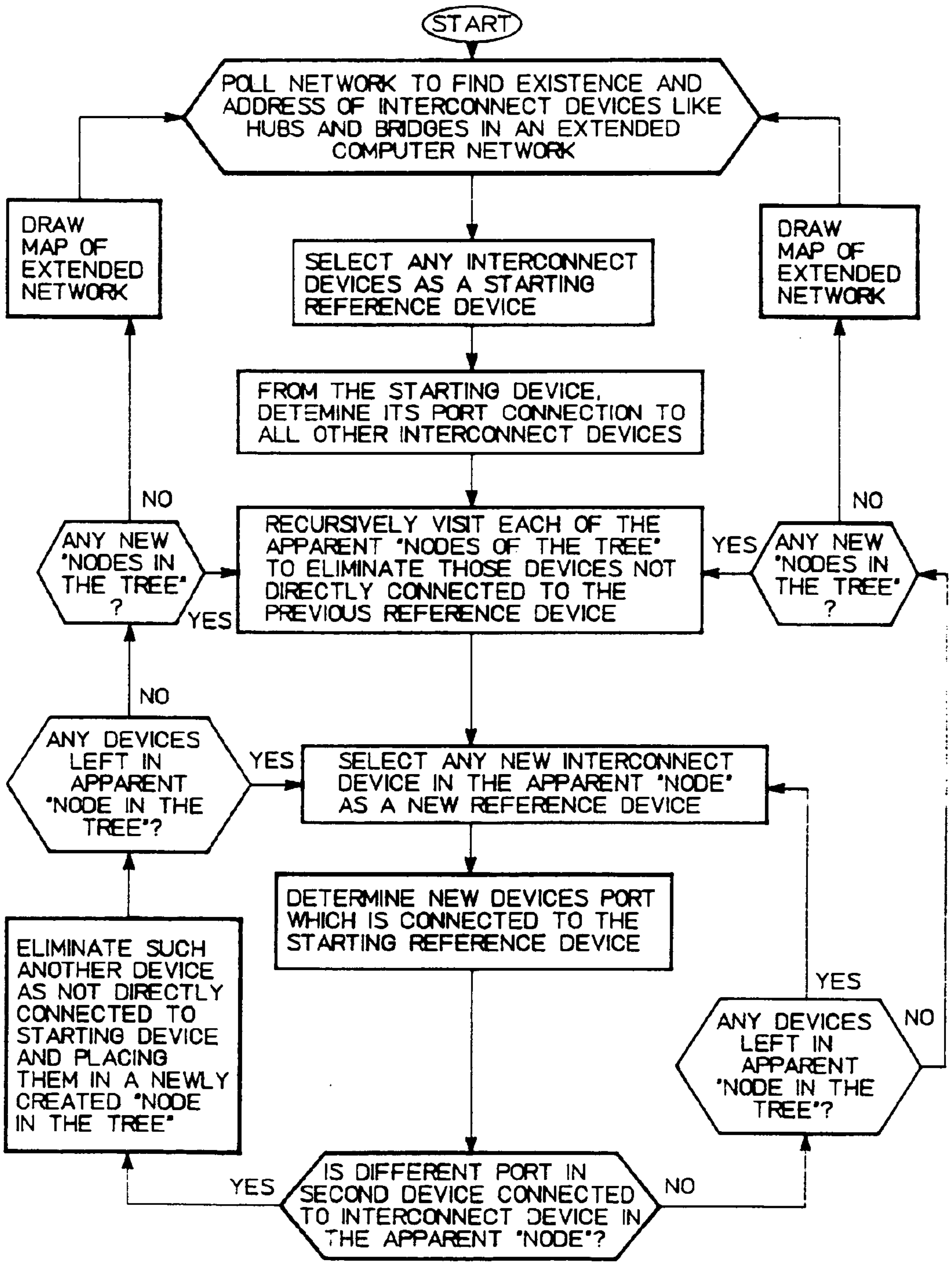

CSMA/CD FRAME FORMAT
START FRAME DELIMITER
DESTINATION ADDRESS
SOURCE ADDRESS
LENGTH COUNT
LOGICAL LINK CONTROL DATA
PAD BYTES
FRAME CHECK SEQUENCE
END FRAME DELIMITER
DSAP
SSAP
CONTROL FIELD
INFORMATION
LOGICAL LINK CONTROL FRAME FORMAT

FIG 13



PHYSICAL TOPOLOGY FLOW CHART

FIG 14

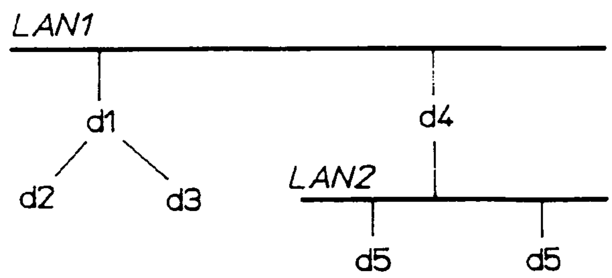


FIG 15A

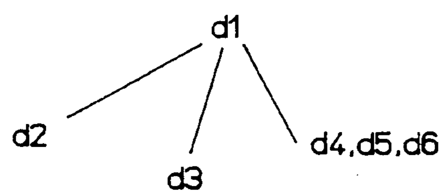


FIG 15B

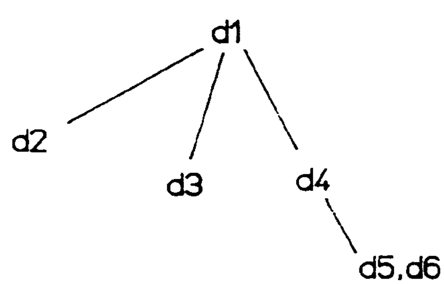
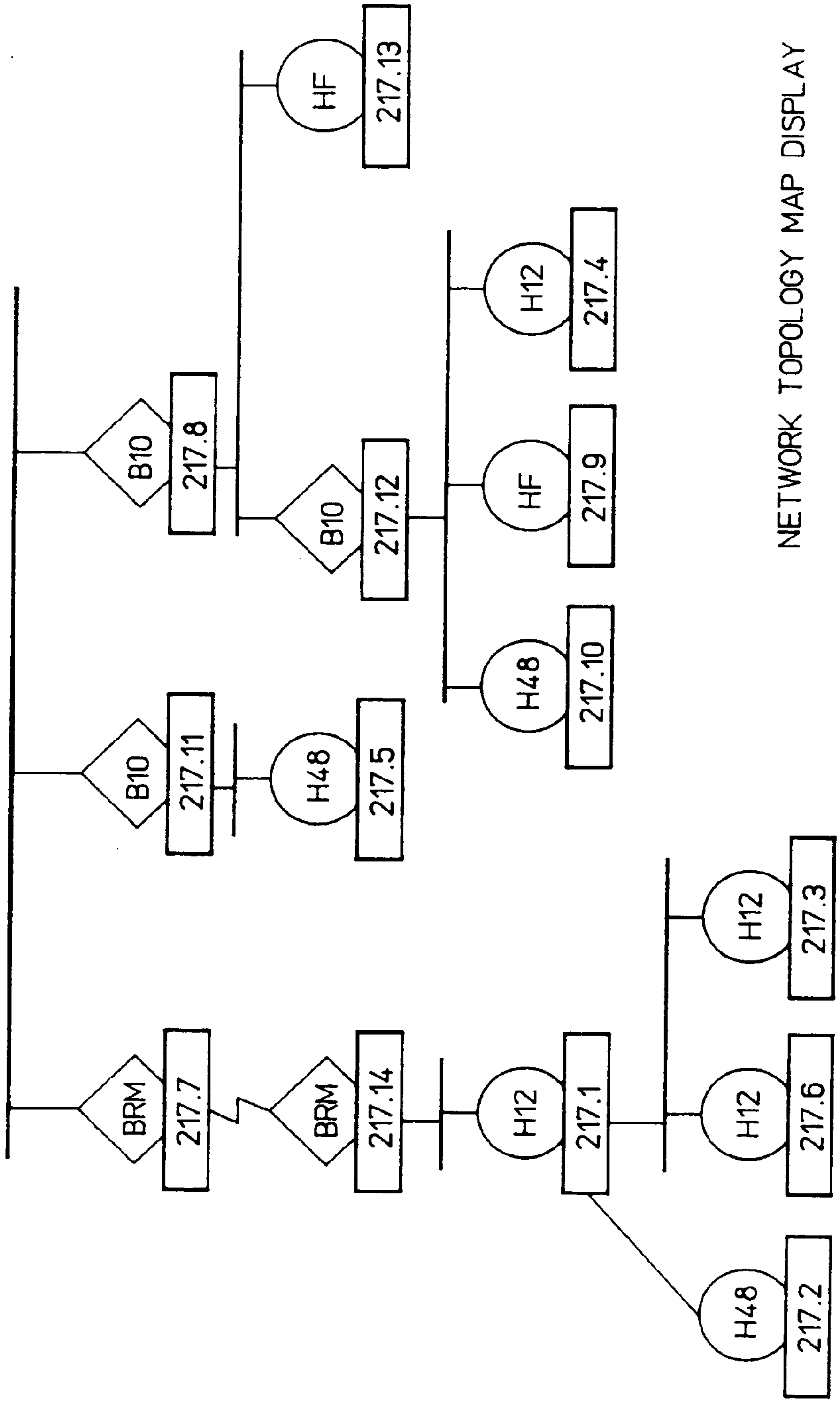


FIG 15C



NETWORK TOPOLOGY MAP DISPLAY

FIG 16

```
+--------+             +-------+
|  Hub 1 |             | Hub 2 |
+--------+             +-------+
       |   Segment A     | | |  Segment B
       +-----------------+ | +----------------+
                           |
                     +-----------+
                     |  Mapping  |
                     |Application|
                     +-----------+
```

Figure 17

```
        +--------+      +---------+      +-------+
        |  Hub 1 |      |  Bridge |      | Hub 2 |
        +--------+      +---------+      +-------+
          |   |              |    |          |   |
+-------+  +-----------+    +-----------+    +-----------+
                                                   |
                                             +-----------+
                                             |  Mapping  |
                                             |Application|
                                             +-----------+
```

Figure 18

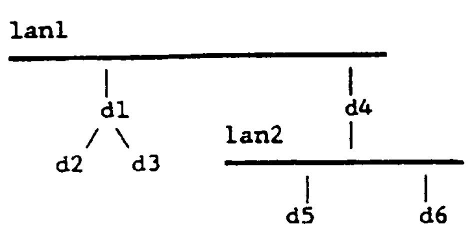


Fig.19